
Programming and Interfacing the 8051 Microcontroller in C and Assembly

Sencer Yeralan, P.E., Ph.D.
Helen Emery

Rigel Press, a Division of Rigel Corporation

Table of Contents

TABLE OF CONTENTS	III
ACKNOWLEDGEMENTS.....	IX
PREFACE	XI
CHAPTER 1 ARCHITECTURE.....	1
1.1. MICROPROCESSORS AND MICROCONTROLLERS	1
1.2. THE 8051 MICROCONTROLLER FAMILY ARCHITECTURE	2
1.2.1. On-Chip Memory	6
1.2.2. Using the On-Chip Facilities	12
CHAPTER 2 ASSEMBLY LANGUAGE PROGRAMMING.....	27
2.1. BACKGROUND	27
2.2. DATA TRANSFER INSTRUCTIONS.....	33
2.2.1. The Immediate Addressing Mode	35
2.2.2. The Direct Addressing Mode	37
2.2.3. The Register Addressing Mode	39
2.2.4. The Register-Specific Addressing Mode	40
2.2.5. The Register Indirect Addressing Mode	41
2.2.6. The Register Indexed Addressing Mode	44
2.2.7. Stack-Oriented Data Transfer.....	45
2.2.8. Exchange Instructions	46
2.2.9. Bit-Oriented Data Transfer.....	47
2.3. DATA PROCESSING INSTRUCTIONS	50
2.3.1. Arithmetic Instructions	50
2.3.2. Logic Instructions	60
2.4. PROGRAM FLOW CONTROL INSTRUCTIONS.....	66
2.4.1. Unconditional Jump Instructions	67
2.4.2. Conditional Jump Instructions	71
2.4.3. Call and Return Instructions	75
2.4.4. Subroutines and Interrupt Service Routines	78
2.5. ENHANCED MEMBERS OF THE 8051 FAMILY	83
2.5.1. Fast Microcontrollers	84
2.5.2. Enhanced Memory Options	84
2.5.3. Additional Data Pointers.....	85
2.5.4. The Multiply and Divide Unit of the 80C517	87
2.5.5. 10-Bit Analog-to-Digital Conversion	89
2.5.6. The I ² C Bus Support	89

2.5.7. ARCNET Token Bus Network Support.....	90
2.5.8. Controller Area Network (CAN) Bus Support.....	91
2.5.9. Universal Serial Bus (USB) Support.....	92
2.5.10. System-On-Chip 8051's.....	92
2.5.11. Migrating to 16-Bit Architectures	93
2.5.12. Information Sources	93
CHAPTER 3 ASSEMBLY LANGUAGE TECHNIQUES.....	95
3.1. INTRODUCTION	95
3.2. DATA BLOCK TRANSFER ROUTINES	95
3.3. TABLE LOOK UP PROCEDURES.....	96
3.4. ASCII CONVERSION ROUTINES	99
3.5. JUMP TABLES	103
3.6. N-WAY BRANCHING	107
3.7. SIGNED ARITHMETIC ROUTINES.....	109
3.7.1. Two's Complement Conversion Routines.....	110
3.7.2. 8-Bit Signed Addition and Subtraction.....	113
3.7.3. 8-Bit Signed Multiplication and Division.....	114
3.8. 16-BIT UNSIGNED ARITHMETIC ROUTINES	115
3.8.1. 16-Bit Addition and Subtraction.....	115
3.8.2. 16-Bit Unsigned Multiplication and Division.....	116
3.9. 16-BIT SIGNED ARITHMETIC ROUTINES	123
3.9.1. 16-Bit Signed Addition and Subtraction.....	123
3.9.2. 16-Bit Signed Multiplication and Division.....	124
3.10. FLOATING-POINT ARITHMETIC ROUTINES.....	125
3.10.1. Floating-Point Multiplication and Division	125
3.11. PSEUDO-RANDOM NUMBERS.....	132
3.12. STRING MANIPULATION ROUTINES	133
3.13. SOFTWARE TIMING ROUTINES	139
3.14. RE-ENTRANT ROUTINES.....	141
3.15. SOFTWARE STACKS	143
3.16. MACRO DEFINITIONS, PREPROCESSOR DIRECTIVES, AND CONDITIONAL ASSEMBLY	144
CHAPTER 4 INTRODUCTORY ASSEMBLY LANGUAGE EXPERIMENTS.....	149
4.1 INPUT/OUTPUT OPERATIONS.....	150
4.2. A SUBROUTINE FOR DRIVING SEVEN-SEGMENT DISPLAYS	151
4.3. SERIAL COMMUNICATIONS	154
4.4. INTERRUPT SERVICE ROUTINES.....	158
4.4.1. Using an Interrupt Vector Table to Redirect the Interrupts	161
4.4.2. Using Multiple Interrupts	163
4.5. COUNTER OPERATIONS	164
4.6. TIMER OPERATIONS	168

4.7. USING THE PTRA UNIT COMPARE AND CAPTURE FUNCTIONS	171
4.7.1. Pulse Train Generation with the PTRA Unit	171
4.7.2. Pulse Width Modulation	174
4.7.3. Pulse Width and Period Measurement	176
4.7.4. Software Timers Using the PTRA Unit	184
4.8. ANALOG-TO-DIGITAL CONVERTER	185
4.8.1. Interrupt-Driven Timer and Analog-to-Digital Conversion Operation	187
4.8.2. 10-Bit Resolution with the Analog-to-Digital Conversion	194
4.9. SERIAL COMMUNICATIONS	201
CHAPTER 5 C LANGUAGE PROGRAMMING.....	207
5.1. C FOR MICROCONTROLLERS	207
5.1.1. In-Line Assembly	207
5.1.2. C Extensions	208
5.1.3. The Reads51 SmallC-Compatible Compiler	210
5.1.3.1. Mixed C / Assembly Module Projects	211
5.2. INTRODUCTORY C LANGUAGE EXPERIMENTS	212
5.2.1. Input/Output Operations	213
5.2.2. A C Function for Driving Seven-Segment Displays	214
5.2.3. Serial Communications	215
5.2.4. Interrupt Service Routines	223
5.2.5. Timer and Counter Operations	224
5.2.6. Analog-to-Digital Conversion	227
5.3. MULTITASKING AND MULTITHREADING	229
5.3.1. A Real-Time Multitasking Utility: RTMT	231
5.3.2. Using the RTMT Utility	239
5.3.3. Inter-Task Synchronization	245
CHAPTER 6 HARDWARE EXPERIMENTS.....	249
6.1. IMPLEMENTING SIMPLE BOOLEAN FUNCTIONS	249
6.1.1. Combinational Logic	250
6.1.2. Sequential Logic	252
6.2. SCANNING A KEYPAD	254
6.3. STEPPER MOTOR CONTROL	268
6.4. A FREQUENCY GENERATOR WITH TIMERS	278
6.5. MEASURING TEMPERATURE AND LIGHT INTENSITY WITH AN ANALOG-TO-DIGITAL CONVERTER	282
6.6. DIGITAL-TO-ANALOG CONVERSION	291
6.6.1. Pulse Width Modulation	292
6.6.2. Using Digital-to-Analog Converter Chips	300
6.7. DC MOTOR SPEED REGULATION WITH A FEEDBACK SYSTEM	304
6.8. INTELLIGENT PERIPHERALS - INTERFACING WITH LIQUID CRYSTAL DISPLAYS.....	313
6.9. IMPLEMENTING A MULTI-DROP RS-485 NETWORK	336

6.9.1. A Simple Network Protocol	341
CHAPTER 7 BUILDING AN 8051-BASED MICROCONTROLLER SYSTEM.....	349
7.1. HARDWARE	349
7.1.1. An 8051-Based System.....	349
7.1.2. 8051-Based System Bill of Materials.....	354
7.1.3. An 80C515-Based System.....	357
7.1.4. 80C515-Based System Bill of Materials	361
7.2. INTERFACING THE MICROCONTROLLER SYSTEM	363
7.3. FIRMWARE	368
7.3.1. MINMON - A Minimal 8051 Monitor Program	368
7.3.2. Setting Up an Interrupt Vector Table	383
7.4. USING THE MICROCONTROLLER SYSTEM TO RUN THE EXAMPLE PROGRAMS	385
CHAPTER 8 DEVELOPING MICROCONTROLLER APPLICATIONS	387
8.1. SUGGESTED APPLICATIONS	387
8.2. THE SOFTWARE DEVELOPMENT CYCLE	388
BIBLIOGRAPHY	391
	391
APPENDIX A READS51 SOFTWARE	395
APPENDIX B A BRIEF REVIEW OF THE C PROGRAMMING LANGUAGE	397
B.1 C LANGUAGE PHILOSOPHY	397
B.1.1 Ingredients of a C Program	398
B.1.2 Code Appearance and Style.....	398
B.2 FUNCTIONS.....	399
B.3 VARIABLES	399
B.3.1 Scalars	399
B.3.2 Pointers	400
B.3.3 Arrays	401
B.4 CONSTANTS.....	402
B.4.1 Compiler Directives	402
B.5 STATEMENTS	402
B.5.1 Compound Statements.....	402
B.5.2 Expressions	403
B.5.3 Conditions.....	404
B.5.4 Iteration Statements	404
B.5.5 Selection Statements	408
B.6 COMMENTS.....	409
B.7 STANDARD (RUN TIME) LIBRARIES	410

B.8 REFERENCES.....	410
APPENDIX C NUMBER SYSTEMS.....	411
C.1 BINARY NUMBERS	411
C.2 HEXADECIMAL NUMBERS	412
C.3 BINARY-CODED DECIMAL NUMBERS.....	413
C.4 TWO'S-COMPLEMENT CONVENTION FOR SIGNED NUMBERS.....	413
APPENDIX D 8051 TOOLS AND INFORMATION SOURCES.....	417
D.1. DIRECTORIES AND PERIODICALS	417
D.2. CHIP MANUFACTURERS	418
D.3. SOFTWARE VENDORS	420
D.4. HARDWARE VENDORS	425
D.4.1. Single-Board Computers.....	425
D.4.2. Parts Suppliers	427
INDEX	429